D E C L A R A T I O N

In the matter of U.S. Patent Application Ser. No. 10/655,582 in the name of Keiji KASHIMA

I, Mariko ENDO, of Kyowa Patent and Law Office, 2-3, Marunouchi 3-Chome, Chiyoda-Ku, Tokyo-To, Japan, declare and say:

that I am thoroughly conversant with both the Japanese and English languages; and,

that the attached document represents a true English translation of Japanese Patent Application No. 2002-261717 filed on September 6, 2002.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Dated: May 25, 2007

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Name of Document: Patent Application

Reference Number: DP0594

Application Date: September 6, 2002

To: The Commissioner of the Patent Office

International Patent Classification: G02F 1/1335

Title of the Invention: LAMINATED RETARDATION OPTICAL ELEMENT, PROCESS OF PRODUCING THE SAME, AND LIQUID CRYSTAL DISPLAY

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Account Number: 006622
Fee: 21,000 Yen

List of Documents filed:

Specification	1
Drawing	1
Abstract	1
Number of General Power of Attorney	9001561

Proofreading: Needed

[Document Type] SPECIFICATION 2002-261717

[Title of Invention] LAMINATED RETARDATION OPTICAL ELEMENT, PROCESS OF PRODUCING THE SAME, AND LIQUID CRYSTAL DISPLAY

[Claims]

[Claim 1]

A laminated retardation optical element comprising: a first retardation layer; and a second retardation layer that is optically bonded to said first retardation layer in this order on a transparent substrate, wherein at least one of said first retardation layer and second retardation layer comprises a cross-linked nematic liquid crystal or a cross-linked nematic liquid crystal and a cross-linked chiral agent as principal component.

[Claim 2]

The laminated retardation optical element according to claim 1, wherein one of said first retardation layer and second retardation layer is a $\lambda/2$ retardation layer while the other is a $\lambda/4$ retardation layer, and an angle between an axis of phase advance of the $\lambda/2$ retardation layer and that of the $\lambda/4$ retardation layer is 60 ± 10 degrees.

[Claim 3]

The laminated retardation optical element according to claim 2, further comprising a third retardation layer having a C plate on said second retardation layer.

[Claim 4]

The laminated retardation optical element according to any one of claims 1 to 3, wherein one of said first retardation layer and second retardation layer consists of an A plate and the other consists of the C plate, respectively.

[Claim 5]

The laminated retardation optical element according to any one of claims 1 to 3, wherein said first retardation layer and second retardation layer respectively consist of the C plate.

[Claim 6]

The laminated retardation optical element according to claim 3 or 5, wherein said

C plate has a thickness of 5 μm or less.

[Claim 7]

The laminated retardation optical element according to claim 5, wherein a total thickness of the C plate constituting said first retardation layer and the C plate constituting said second retardation layer is 8 μm or more, and said two C plates have substantially the same thickness.

[Claim 8]

The laminated retardation optical element according to any one of claims 1 to 7, wherein a linearly polarizing plate is bonded to a surface opposite said first retardation layer in said transparent substrate.

[Claim 9]

The laminated retardation optical element according to any one of claims 1 to 8, wherein a difference between mean refractive indices of said first retardation layer and said second retardation layer is 0.05 or less.

[Claim 10]

The laminated retardation optical element according to any one of claims 1 to 9, wherein cross-linked nematic liquid crystalline components contained in said first retardation layer and said second retardation layer are the same.

[Claim 11]

The laminated retardation optical element according to any one of claims 1 to 10, wherein said first retardation layer is subjected to patterning into said transparent substrate and said second retardation layer is subjected to patterning into said first retardation layer, respectively.

[Claim 12]

A process of producing a laminated retardation optical element, which is a process of producing the laminated retardation optical element according to any one of claims 1 to 11, comprising the steps of: forming a film by cross-linking a cross-linkable nematic liquid crystal coated on an oriented film on a transparent substrate, or the cross-linkable nematic liquid crystal and a cross-linkable chiral agent; and forming a film by further coating and cross-linking on said film the cross-linkable nematic liquid

crystal, or the cross-linkable nematic liquid crystal and the cross-linkable chiral agent.

[Claim 13]

The process of producing a laminated retardation optical element according to claim 12, wherein an alignment regulation power on the surface of said first retardation layer is used to align said second retardation layer.

[Claim 14]

The process of producing a laminated retardation optical element according to claim 13, wherein the surface of said first retardation layer is subjected to rubbing treatment to align said second retardation layer.

[Claim 15]

The process of producing a laminated retardation optical element according to claim 12, wherein an alignment film is further formed on the surface of said first retardation layer and said second retardation layer is aligned using the alignment regulation power of said alignment film.

[Claim 16]

The process of producing a laminated retardation optical element according to claim 15, wherein the alignment regulation power of said alignment film is embodied with rubbing to said alignment film.

[Claim 17]

The process of producing a laminated retardation optical element according to claim 15, wherein the alignment regulation power of said alignment film is embodied with light irradiation to said alignment film.

[Claim 18]

A liquid crystal display comprising the laminated retardation optical element according to any one of claims 1 to 11 as a transparent substrate of a display element.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a laminated retardation optical element, a

process of producing the same and a liquid crystal display, especially to a laminated retardation optical element having the function of effectively compensating for the change of the optical properties of a liquid crystal while, at the same time, realizing high productivity and heat resistance, the process of producing the same and a liquid crystal display comprising the laminated retardation optical element.

[0002]

[Prior Art]

Fig. 12 is an exploded view showing an example of a structure of a standard liquid crystal display.

[0003]

The conventional liquid crystal display 100 comprises a polarizer 102A on the incident side, a polarizer 102B on the emergent side, and a liquid crystal cell 104. The polarizers 102A and 102B are so constructed that they selectively transmit only linearly polarized light, having planes of vibration in predetermined directions, and are arranged in the cross nicol disposition so that the said predetermined directions are perpendicular with each other. The liquid crystal cell 104 comprises a large number of cells and is placed between the polarizers 102A and 102B.

[0004]

The case where the liquid crystal cell 104 is of VA mode, in which a nematic liquid crystal having negative dielectric anisotropy is sealed, is now taken as an example. Linearly polarized light that has transmitted the polarizer 102A on the incident side undergoes a phase shift when it passes through those cells that are in the driven state, and transmits and emerges from the polarizer 102B on the emergent side. On the contrary, when those cells are in the non-driven state, the linearly polarized light that has passed through the polarizer 102A on the incident side passes through those cells without undergoing a phase shift and is blocked by the polarizer 102B on the emergent side. In addition, there is also a liquid crystal display so constructed that light emerging from those cells in the non-driven state emerges from the polarizer on the emergent side, and that the light emerging from those cells in the driven state is blocked. It is possible to display the desired image on the emergent-side polarizer 102B side by properly controlling

the driving voltage that is applied to the liquid crystal cell 104.

[0005]

On the other hand, the liquid crystal cell 104 is birefringent, and its refractive index in the direction of thickness and that in the direction of plane are different from each other. Therefore, of the linearly polarized light that passed through the polarizer 102A on the incident side, the light that has entered from the normal to the slanting direction becomes elliptically polarized light with a phase difference generated when passing through the liquid crystal cell 104. The amount of the phase difference is also influenced by anisotropy of a refractive index of the liquid crystalline molecules sealed in the liquid crystal cell 104, the thickness of the cell, and the wavelength of the transmitted light.

[0006]

Therefore, even when certain cells are in the non-driven state and linearly polarized light is supposed to be transmitted as it is and blocked by the polarizer 102B on the emergent side, part of the light that has transmitted from the normal to the slanting direction occasionally leaks from the polarizer 102B on the emergent side.

[0007]

For this reason, the liquid crystal display 100 has a viewing angle dependency problem that the image display quality (contrast etc.) at the time when an image is viewed from a slanting direction from the normal is apt to be inferior to that at the time when the image is viewed from the front thereof.

[0008]

To eliminate such a viewing angle dependency problem with the liquid crystal display 100, there have been developed a variety of liquid crystal displays having a retardation layer that comprises high-molecular liquid crystals between the liquid crystal cell 104 and the polarizers 102A and 102B so that the said retardation layer provides optical compensation.

[0009]

[Problems to be Solved by the Invention]

However, the conventional retardation layer comprising high-molecular liquid crystals has its view angle properties not necessarily sufficiently compensated optically

while it is advantageous in that lightweight and thinning solutions are relatively easy. In particular, the high-molecular liquid crystals cannot be used at a temperature of 100 degrees Celsius or higher as its glass state and liquid crystalline state are reversible. In addition, when the crystals are laminated, they are mixed between the layers and target optical properties cannot be obtained.

[0010]

The present invention was accomplished in the light of the aforementioned drawbacks, and an object thereof is to provide: a laminated retardation optical element that can effectively compensate for the change in the optical properties of a liquid crystal cell while achieving high productivity and heat resistance at the same time; a process of producing such an element; and a liquid crystal display comprising the said laminated retardation optical element.

[0011]

[Means for Solving the Problems]

The present invention provides a first retardation layer and a second retardation layer that is optically bonded to the said first retardation layer in sequence on a transparent substrate. At least one of the said first retardation layer and second retardation layer comprises a cross-linked nematic liquid crystal or the cross-linked nematic liquid crystal and a cross-linked chiral agent as main component, thereby solving the above-described problems.

[0012]

In other words, in the present invention, the laminated retardation optical element has a two-layer structure consisting of the first retardation layer and the second retardation layer. Therefore, it is possible to compensate different optical properties that are different in the respective retardation layers and to compensate a change in optical property generated by a liquid crystalline cell very effectively thanks to a synergy effect of each optical compensation. Therefore, for example, one of the said first retardation layer and second retardation layer comprises a $\lambda/2$ retardation layer and the other comprises a $\lambda/4$ retardation layer respectively. At the same time, the laminated retardation optical element may be configured so that the angle between the

axis of phase advance of the said $\lambda/2$ retardation layer and that of the $\lambda/2$ retardation layer is 60 ± 10 degrees. Furthermore, the laminated retardation optical element may also be configured so that one of the said first retardation layer and second retardation layer comprises an A plate and the other comprises a C plate respectively. In addition, it is preferable that the said C plate has a thickness of 5 μm or less or the total thickness of the C plate constituting said first retardation layer and the C plate constituting said second retardation layer is 8 μm or more; and the thickness of the said two C plates are nearly equal with each other.

[0013]

Further, the laminated retardation optical element may comprise a third retardation layer consisting of the C plate on the said second retardation layer.

[0014]

Further, a main component of at least one of the first retardation layer and the second retardation layer is a cross-linked nematic liquid crystal or the cross-linked nematic liquid crystal and a cross-linked chiral agent. Therefore, it is possible to use the nematic liquid crystal and a cholesteric liquid crystal in combination, whose birefringent embodiments are different in terms of a direction. Moreover, since the laminated retardation optical element has sufficient strength, heat resistance and impact resistance, it can be used even in a harsh environment with a temperature of 100 degrees Celsius or higher. Furthermore, the elements do not mix between layers and can have excellent optical properties even when they are laminated.

[0015]

Furthermore, the laminated retardation optical element may have a linearly-polarizing plate bonded to a surface opposite the said first retardation layer on the said transparent substrate. The laminated retardation optical element may also be configured so that the said first retardation layer is patterned on the said transparent substrate and the said second retardation layer is patterned on the said first retardation layer, respectively.

[0016]

In addition, the laminated retardation optical element may also be configured so that the cross-linked nematic liquid crystalline components contained in the said first

retardation layer and the said second retardation layer are the same.

[0017]

Furthermore, it is preferable that the difference between the mean refractive indices of the said first retardation layer and the second retardation layer is 0.05 or less in order to obtain a higher optical compensation effect.

[0018]

When the above-mentioned laminated retardation optical element is produced, which comprises the steps of: forming a film by cross-linking a cross-linkable nematic liquid crystal coated on an oriented film on a transparent substrate, or the cross-linkable nematic liquid crystal and a cross-linkable chiral agent; and forming a film by further coating and cross-linking on the said film the cross-linkable nematic liquid crystal, or the cross-linkable nematic liquid crystal and the cross-linkable chiral agent, it is easier to produce the element.

[0019]

Further, an alignment regulation power on the surface of the said first retardation layer is used to align the said second retardation layer so that the element can be obtained at high productivity. For example, the surface of the said first retardation layer may be subjected to rubbing treatment to align the said second retardation layer.

[0020]

Further, an alignment film may further be formed on the surface of the said first retardation layer, and the said second retardation layer may be aligned using the alignment regulation power of the said alignment film. The alignment regulation power of this alignment film can be embodied with rubbing to the alignment film and light irradiation.

[0021]

A liquid crystal display comprising the above-described laminated retardation optical element as a transparent substrate of a display element may be used.

[0022]

[Forms to Implement the Invention]

Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

[0023]

Fig. 1 is a perspective view showing an example that a laminated retardation optical element according to an embodiment of the present invention is incorporated in a liquid crystal display 90.

[0024]

The said liquid crystal display 90 has the laminated retardation optical element 10 arranged between a polarizer 102B on the incident side and a liquid crystal cell 104 with respect to a conventional liquid crystal display 100 illustrated in the said Fig. 12. An explanation about the other configurations will be omitted as it is the same as that about the said laminated retardation optical element 10.

[0025]

Next, the principle of optical compensation by the laminated retardation optical element 10 according to the embodiment of the present invention will be explained with reference to an example.

[0026]

Fig. 2 is a diagrammatic view showing the principle of optical compensation that is provided in the case where the liquid crystal cell 104 in the liquid crystal display 90 is in the non-driven state and where a non-polarized light ray W1 emitted from a light source, not shown, enters the liquid crystal display 90. In this figure, the symbols "←→" and "•" both indicate the electrical field oscillation vector of linearly polarized light, where "←→" indicates the direction of paper plane and "•" indicates the direction vertical to the paper plane.

[0027]

Non-polarized light W1 from a light source, not shown, has its linearly polarized component in the direction "•" absorbed by the polarizer 102A on the incident side, but the linearly polarized component in the direction "←→" transmits the polarizer 102A to become linearly polarized light W2. The said linearly polarized light W2 transmits the liquid crystal cell 104 in the non-driven state as it is when transmitting straightly, but the light W2 in the slanting direction is converted to circularly polarized light W3 with a phase difference (retardation) generated by birefringence of the liquid

crystal cell 104. In the circularly polarized light W3, the retardation generated in the liquid crystal cell 104 is offset by the laminated retardation optical element 10 and is converted to a state close to linearly polarized light W4 that has only the linearly polarized component in the direction "←→". Consequently, most of the linearly polarized light W4 can be blocked by a polarizer 102B on the emergent side that transmits only the linearly polarized component in the direction "•".

[0028]

As described above, the laminated retardation optical element 10 is arranged on the liquid crystal display 90 and the retardation of the liquid crystal cell 104 is optically compensated, so that it is possible to prevent leakage of light from the polarizer 102B on the emergent side and to improve a viewing angle characteristic of the liquid crystal display 90.

[0029]

Next, the construction of the laminated retardation optical element 10 according to an embodiment of the present invention will be explained in detail with reference to Fig. 3. Fig. 3 is an enlarged diagrammatic and perspective view showing the laminated retardation optical element 10 illustrated in Fig. 1.

[0030]

The said laminated retardation optical element 10 is configured to comprise a first retardation layer 14 (hereinafter, referred to only as first retardation layer) and a second retardation layer 16 (hereinafter, referred to only as second retardation layer) that is optically bonded to the said first retardation layer 14 in this order on a transparent substrate 12. In addition, at least one of the said first retardation layer 14 and second retardation layer 16 comprises a cross-linked nematic liquid crystal or a cross-linked nematic liquid crystal and a cross-linked chiral agent as principal component.

[0031]

Three-dimensionally cross-linkable liquid crystalline monomers or liquid crystalline oligomers can be used as materials for the said nematic liquid crystal. If a chiral agent is optionally added to the nematic liquid crystal in an amount of approximately several to 10%, a chiral nematic liquid crystal (cholesteric liquid crystal)

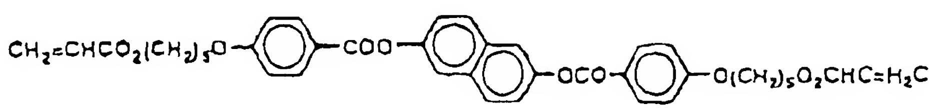
can be obtained. "Three-dimensional cross-linking" herein means that liquid crystalline monomer or oligomer molecules are three-dimensionally polymerized to give a mesh (network) structure. In such a state, it is possible to optically fix the liquid crystalline molecules with its cholesteric structure or nematic structure maintained and thus, to obtain a film as an optical film and is stable at normal temperatures.

[0032]

Mixtures of liquid crystalline monomers and chiral compounds as disclosed, for example, in Japanese Laid-Open Patent Publication No. 258638/1995 and Published Japanese Translation No. 508882/1998 of PCT International Publication for Patent Application can be used as the three-dimensionally cross-linkable monomers. More specifically, it is possible to use liquid crystalline monomers represented by general chemical formulae (1) to (11). In liquid crystalline monomers represented by general chemical formula (11), X is preferably 2 to 5 (an integer).

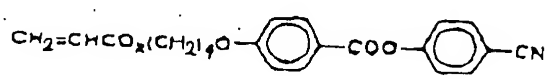
[0033]

[Chemical formula 1]



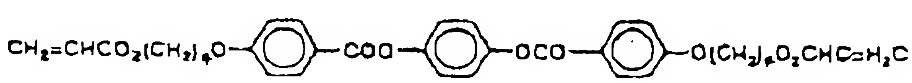
[0034]

[Chemical formula 2]



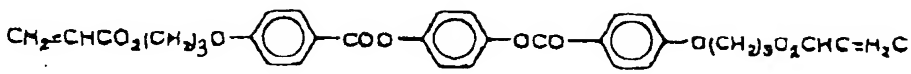
[0035]

[Chemical formula 3]



[0036]

[Chemical formula 4]

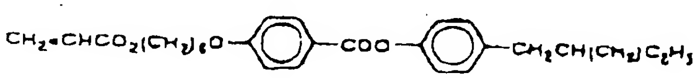


[0037]

[Chemical formula 5]

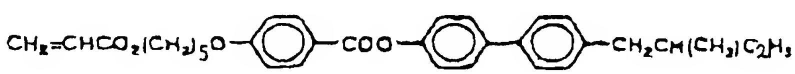
[0038]

[Chemical formula 6]



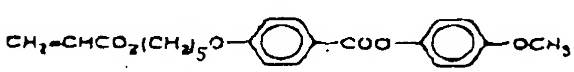
[0039]

[Chemical formula 7]



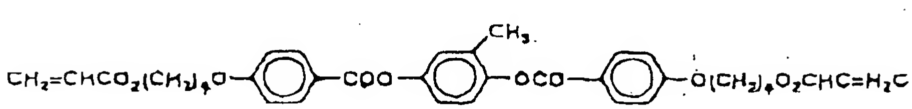
[0040]

[Chemical formula 8]



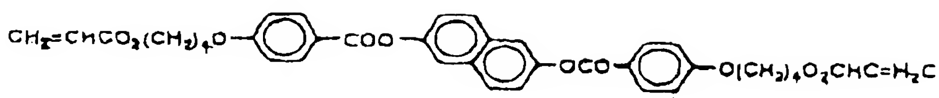
[0041]

[Chemical formula 9]



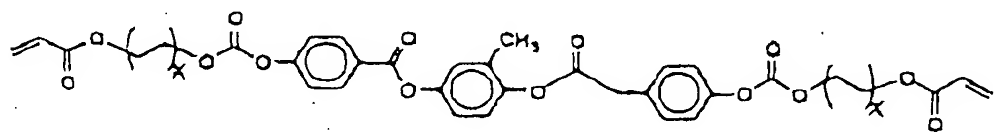
[0042]

[Chemical formula 10]



[0043]

[Chemical formula 11]

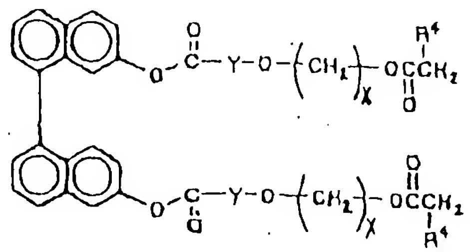


[0044]

In addition, chiral agents represented by general chemical formulae (12) to (14), for example, can be used as chiral agents. Further, in chiral agents represented by general chemical formulae (12) and (13), X is preferably 2 to 12 (an integer); and in chiral agents represented by general chemical formula (14), X is preferably 2 to 5 (an integer).

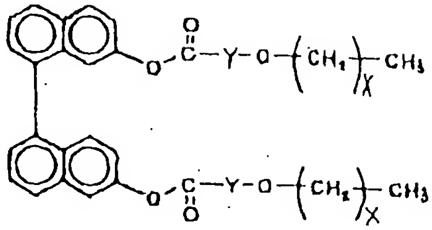
[0045]

[Chemical formula 12]



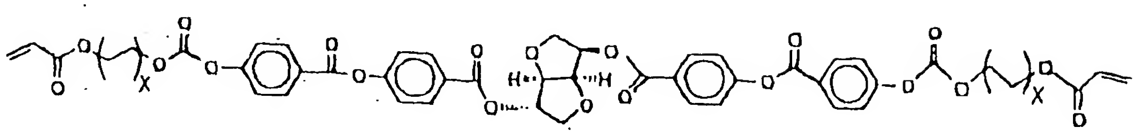
[0046]

[Chemical formula 13]



[0047]

[Chemical formula 14]



[0048]

Further, it is desirable to use, as the oligomers, cyclic organopolysiloxane compounds having cholesteric phases as disclosed in Japanese Laid-Open Patent Publication No. 165480/1982.

[0049]

The nematic liquid crystal has double refractivity, so its refraction index in the direction of directors of liquid crystalline molecules is different from that in the direction vertical to the directors. Therefore, even in the direction of a plane, the refractive index in the direction of the directors is different from that in the direction vertical to the directors. In addition, the refractive index in the direction of the plane, vertical to the directors, is equal to the refractive index in the direction of thickness.

[0050]

On the contrary, the cholesteric liquid crystal has significant double refractivity to light longer than its selective reflection wavelength, so that its refractive index in the direction of thickness is different from that in the direction of the plane. Therefore, a phase difference can be generated in the linearly-polarized light in the direction slantingly

deviating from the normal to the laminated retardation optical element 10, thereby converting the light into elliptically polarized light and, on the other hand, can also convert elliptically polarized light in the direction slantingly deviating from the normal into linearly polarized light. In addition, linear polarized light transmitting in the direction of the normal is transmitted as it is as linear polarized light without generating a phase difference.

[0051]

According to the laminated retardation optical element 10 according to the embodiment of the present invention, the said laminated retardation optical element 10 is composed of two retardation layers consisting of the first retardation layer 14 and the second retardation layer 16. The respective retardation layers 14 and 16 can compensate the different optical properties and, owing to their synergetic effects, can very effectively compensate for changes in optical properties that are caused by the liquid crystal cell 104.

[0052]

Moreover, in the laminated retardation optical element 10, a cross-linked nematic liquid crystal or the cross-linked nematic liquid crystal and a cross-linked chiral agent are used as main components of the first retardation layer 14 and the second retardation layer 16. Therefore, retardation layers having directionally different embodiment of birefringence (nematic retardation layer and cholesteric retardation layer) can be used in combination. Further, as the element has sufficient strength, heat resistance and impact resistance, it can be used even in a severe environment at 100°C or higher. In addition, in the process of lamination, the layers never mingle with each other, so that it is possible to obtain excellent optical properties.

[0053]

Figs. 4(A) and (B) are perspective views showing laminated retardation optical elements 20A and 20B in which one of the said first retardation layer 14 and second retardation layer 16 is a $\lambda/2$ retardation layer and the other is a $\lambda/4$ retardation layer, respectively. In the laminated retardation optical element 20A shown in (A), the first retardation layer 14 is comprised of the $\lambda/4$ retardation layer 24 and the second retardation layer 16 is comprised of the $\lambda/2$ retardation layer 26, respectively. In the laminated retardation optical element 20B shown in (B), the first retardation layer 14 is

comprised of the $\lambda/2$ retardation layer 26 and the second retardation layer 16 is comprised of the $\lambda/4$ retardation layer 24, respectively.

[0054]

Further, as shown in (C), axes of phase advance L_1 and L_2 of the said $\lambda/4$ retardation layer 24 and $\lambda/2$ retardation layer 26 are layered to cross at an angle of 60 ± 10 degrees. A laminate of the $\lambda/4$ retardation layer 24 and the $\lambda/2$ retardation layer 26 in such an angle range can constitute a $\lambda/4$ retardation layer that covers a wide wave range.

[0055]

Furthermore, the $\lambda/4$ retardation layer 24 has a function to convert incident linearly-polarized light into circularly-polarized light or vice versa, and the $\lambda/2$ retardation layer 26 has a function to invert polarity of polarized light.

[0056]

Thus, it is also possible to optically compensate and obtain a $\lambda/4$ retardation layer that covers a wide wave range with the laminated retardation optical elements 20A and 20B arranged in the liquid crystal display 90, in which the $\lambda/4$ retardation layer 24 and the $\lambda/2$ retardation layer 26 are combined.

[0057]

In addition, as shown in Fig. 4(D), it is also possible to use a laminated retardation optical element 20C that is further equipped with a third retardation layer 28 comprising a C plate to be described later on the second retardation layer 16.

[0058]

Figs. 5(A) and (B) are perspective views showing laminated retardation optical elements 30A and 30B in which one of the said first retardation layer 14 and second retardation layer 16 is an A plate (having an optical axis in the direction of a plane like the said $\lambda/4$ retardation layer 24) 36 and the other is a C plate (having an optical axis in the direction of thickness of a vertically aligned nematic liquid crystal like discotic liquid crystal or cholesteric liquid crystal) 34, respectively. In the laminated retardation optical element 30A shown in (A), the first retardation layer 14 is comprised of the C plate 34 and the second retardation layer 16 is comprised of the A plate 36, respectively. In the laminated retardation optical element 30B shown in (B), the first retardation layer

14 is comprised of the A plate 36 and the second retardation layer 16 is comprised of the C plate 34, respectively.

[0059]

The said A plate 36 is a uniaxial birefringent layer in which an axis of phase delay L3 is aligned to be parallel to the surface of the layer, and is able to compensate phase delay caused by A plate optical properties of the liquid crystal cell 104 and phase delay in the slanting direction of polarizers 102A and 102B. Further, the said C plate 34 is a uniaxial birefringent layer in which an axis of phase delay L4 is aligned to be vertical to the surface of the layer, and is able to compensate phase delay caused by C plate optical properties of the liquid crystal cell 104.

[0060]

Thus, it is possible to effectively offset retardation generated in the liquid crystal cell 104 and the polarizers 102A and 102B and to improve view angle properties of the liquid crystal display 90 also with the laminated retardation optical elements 30A and 30B arranged on the liquid crystal display 90, in which the A plate 36 and the C plate 34 are combined.

[0061]

Fig. 6 is a perspective view showing a laminated retardation optical element 40 in which the said first retardation layer 14 and the second retardation layer 16 are comprised of C plates 44A and 44B, respectively. Also with such a configuration, it is possible to compensate phase delay caused by C plate optical properties of the liquid crystal cell 104 and to obtain the same effect as described above. This is especially effective when retardation in the direction of thickness is insufficient only with a unilaminar C plate.

[0062]

Further, as shown in Fig. 7, it is also possible to impart a linear polarizing effect to a laminated retardation optical element 50 with the said laminated retardation optical element 50 in which a linearly polarizing plate 52 is bonded to a surface 12A opposite the first retardation layer 14 in the transparent substrate 12 of the above-mentioned laminated retardation optical element 10 (20A, 20B, 20C, 30A, 30B or 40).

[0063]

Furthermore, as shown in Fig. 8, it is possible to form two different phase difference regions and provide a laminated retardation optical element 60 according to an application with the laminated retardation optical element 60 in which the said first retardation layer 14 is patterned on the said transparent substrate 12 and the said second retardation layer 16 is patterned on the said first retardation layer 14, respectively.

[0064]

Next, a process of producing the above-mentioned laminated retardation optical element 10 will be described in detail with reference to Fig. 9. Drawings in Fig. 9 are diagrammatic views illustrating a process of producing the laminated retardation optical element 10.

[0065]

First, an alignment layer 18 is formed on a transparent substrate 12 (Fig. 9 (A)). Inorganic materials such as plates of glass, silica and the like, as well as a variety of resins including polyesters such as cellulose acetate, polyethylene terephthalate (PET), polyethylene naphthalate (PEN) and the like; polyimide; polyethylene and the like can be used for the transparent substrate 12. Further, the alignment layer 18 is laminated to the surface of the transparent substrate 12, and polymeric films of polyimide, polyamide imide, polyether imide, polyvinyl alcohol and the like can be used therefor.

[0066]

Next, the alignment layer 18 is subjected to "rubbing" treatment for alignment (Fig. 9(B)). The alignment layer 18 subjected to rubbing treatment becomes such a state that the surface 18A has fine grooves that are formed in one direction (the direction indicated by H1 in the figure), whereby liquid crystalline molecules that come in contact with the surface are aligned.

[0067]

Thereafter, a cross-linkable nematic liquid crystal made from a polymerizable monomer, polymerizable oligomer or the like, or the cross-linkable nematic liquid crystal and a chiral agent are coated on the alignment layer 18 (Fig. 9(C)). The polymerization of the said polymerizable monomer or polymerizable oligomer molecules or the like is

initiated with a photopolymerization initiator that has been added in advance and ultraviolet light that is externally applied, or directly initiated using an electron beam, thereby three-dimensionally cross-linking (polymerizing) and forming a first retardation layer 14 in the form of a film (Fig. 9(D)). In this process, liquid crystalline molecules in the first retardation layer 14 is aligned, in the direction indicated by H1 in the figure, by the alignment regulation power of the alignment layer 18. If the entire region of the alignment layer 18 has been treated so that its alignment regulation power of the same alignment layer 18 acts substantially in the same direction, it is possible to make the directions of the directors of liquid crystalline molecules present on the surface 18A substantially the same within the said surface.

[0068]

In addition, the polymerizable monomer molecules (or polymerizable oligomer molecules) may be coating liquids dissolved in solvents such as toluene. In this case, the drying step is necessary to evaporate the solvents before the step of three-dimensional cross-linking with the application of ultraviolet light or an electron beam.

[0069]

Further, on the first retardation layer 14, a cross-linkable nematic liquid crystal or the cross-linkable nematic liquid crystal and a chiral agent made from a polymerizable monomer, polymerizable oligomer or the like is coated (Fig. 9 (F)) and then, is three-dimensionally cross-linked with the application of ultraviolet light or an electron beam in the same manner as mentioned above, thereby forming a second retardation layer 16 that is in the form of a film (Fig. 9 (G)). In this process, liquid crystalline molecules in the second retardation layer 16 are aligned, in the direction indicated by H2 in the figure, by the alignment regulation power of the surface 14A of the first retardation layer 14.

[0070]

It is easy to produce the laminated retardation optical element 10 with the process of producing the laminated retardation optical element 10 according to the embodiment of the present invention. Moreover, it is possible to improve productivity since liquid crystal molecules of the second retardation layer 16 can be aligned using an

alignment regulation power of a surface 14A of the first retardation layer 14. The element may also be subjected to rubbing when the alignment regulation power of the surface 14A itself is insufficient.

[0071]

Further, the present inventor has found that a C plate 44B has defective alignment, the alignment regulation power of the said C plate 44B is weakened and the laminated retardation optical element 40 is likely to be defectively produced when a thickness h2 of the C plate 44B becomes larger than 5 μm in a process of producing the laminated retardation optical element 40 comprised of the two-layer C plates 44A and 44B. Therefore, when the laminated retardation optical element 40 is composed of the two-layer C plates 44A and 44B, the thicknesses h1 and h2 of the respective C plates 44A and 44B are preferably 5 μm or less, respectively.

[0072]

In addition, the present inventor has found through his examination that the total thickness (h1 + h2) of the thickness h1 of the C plate 44A comprising the said second retardation layer 16 and the thickness h2 of the C plate 44B comprising the said first retardation layer 14 needs to be at least 8 μm in order to obtain a sufficient optical compensation effect. Therefore, for example, it is also possible to constitute the laminated retardation optical element 40 with the C plate 44A of 5 μm (= h1) and the C plate 44B of 3 μm (= h2). However, if the thicknesses h1 and h2 of the respective C plates 44A and 44B are 4 μm, respectively, it is easy to produce the laminated retardation optical element 10 and improve productivity since both plates have no alignment defect and the thicknesses of the two C plates 44A and 44B are substantially the same.

[0073]

Further, as shown in Fig. 10, it is also possible to obtain the same effect with a production process that an alignment layer 19 is further formed on the surface 14A of the first retardation layer 14 (Fig. 10(D)) and then the said alignment layer 19 is aligned in the H2 direction in the drawing with rubbing (Fig. 10(E)), and liquid crystal molecules of the second retardation layer 16 are aligned using the alignment regulation power of the alignment layer 19 (Figs. 10(F) and (G)).

[0074]

In addition, the alignment regulation powers of the alignment layers 18 and 19 and the first retardation layer 14 are embodied with rubbing in the above-mentioned embodiments. However, the present invention is not limited to the embodiments and, for example, may be "photo-alignment" in which the alignment regulation powers are embodied with light irradiation. Here, the "photo-alignment" is to impart anisotropy to a surface of a photo-alignment film by irradiating photoactive molecules such as ad-benzene polymers, polyvinyl cinnamate and the like with linearly-polarized light and slanting unpolarized light that have wavelengths enough to cause a photochemical reaction. Here, an alignment of a molecular length axis on a top surface of a film is generated with incident light, and a driving force to align a liquid crystal contacting molecules on the top surface is formed.

[0075]

Further, according to the embodiment of optical compensation, the laminated retardation optical element 10 may also be arranged between the polarizer 102A on the incident side and the liquid crystal cell 104 or on both sides of the liquid crystal cell 104. Thus, more ideal optical compensation can be realized with the laminated retardation optical element 10 arranged on both sides of the liquid crystal cell 104. In addition, a plurality of the laminated retardation optical elements 10 may be arranged on one side or both sides of the liquid crystal cell 104.

[0076]

In the above embodiments, the liquid crystal display 90 is a transmission type in which light is transmitted from one side of the direction of thickness to the other side. However, the present invention is not limited to this type, and the retardation optical element according to the present invention can also be applied to a reflective or semi-transmissive liquid crystal display.

[0077]

[Examples]

Example 1

An effect of optical compensation of the said laminated retardation optical

element 30B was measured using the laminated retardation optical element 30B illustrated in Fig. 5(B), in which the first retardation layer 14 is comprised of the A plate 36 and the second retardation layer 16 is comprised of the C plate 34, respectively.

[0078]

X and Y in Fig. 11 is a graph showing retardations of the two laminated retardation optical element 30B having different thicknesses, respectively. The graph plots viewing angle (°) as the abscissa and retardation (nm) as the ordinate.

[0079]

As is clear from Fig. 11, the laminated retardation optical elements 30B have optical properties that are equal to the sum of those of the A plate and those of the C plate.

[0080]

Further, according to the laminated retardation optical elements 30B, the C plate 34 can be directly laminated to the A plate 36, so that there is no need to provide a transparent substrate or the like between the C plate 34 and the A plate 36. Thinning of the elements is thus accomplished.

[0081]

[Effect of the Invention]

According to the present invention, it is possible to provide: a laminated retardation optical element that can effectively compensate for the change in the optical properties of a liquid crystal cell while achieving high productivity and heat resistance at the same time; a process of producing such an element; and a liquid crystal display comprising the said laminated retardation optical element.

[Brief Description of the Drawings]

[Fig. 1]

A perspective view showing a liquid crystal display according to an embodiment of the present invention.

[Fig. 2]

A diagrammatic view for explaining an optical principle of the liquid crystal display

shown in Fig. 1.

[Fig. 3]

An enlarged, diagrammatic and perspective view showing a laminated retardation optical element shown in Fig. 1.

[Fig. 4]

Perspective views illustrating a laminated retardation optical element comprised of a $\lambda/4$ retardation layer and a $\lambda/2$ retardation layer.

[Fig. 5]

Perspective views illustrating a laminated retardation optical element comprised of an A plate and a C plate.

[Fig. 6]

A perspective view showing a laminated retardation optical element comprised of a bilayer C plate.

[Fig. 7]

A perspective view showing a laminated retardation optical element to which a linearly-polarizing plate is bonded.

[Fig. 8]

A perspective view showing a laminated retardation optical element to which a first retardation layer and a second retardation layer are patterned.

[Fig. 9]

Diagrammatic views illustrating a process of producing a laminated retardation optical element according to an embodiment of the present invention.

[Fig. 10]

Diagrammatic views illustrating another process of producing a laminated retardation optical element according to an embodiment of the present invention.

[Fig. 11]

A graph showing retardation in the laminated retardation optical elements comprised of the A plate and the C plate according to Example 1 of the present invention.

[Fig. 12]

An exploded, diagrammatic perspective view showing a conventional liquid

crystal display.

[Descriptions of Numerical Symbols]

10, 20A, 20B, 20C 30A, 30B, 40, 50, 60,	Laminated retardation optical element
12	Transparent substrate
14	First retardation layer
16	Second retardation layer
18, 19	Alignment layer
24	λ/4 retardation layer
26	λ/2 retardation layer
36	A plate
34, 44A, 44B	C plate
52	Linearly-polarizing plate
90, 100	Liquid crystal display
102A, 102B	Polarizer
104	Liquid crystal cell

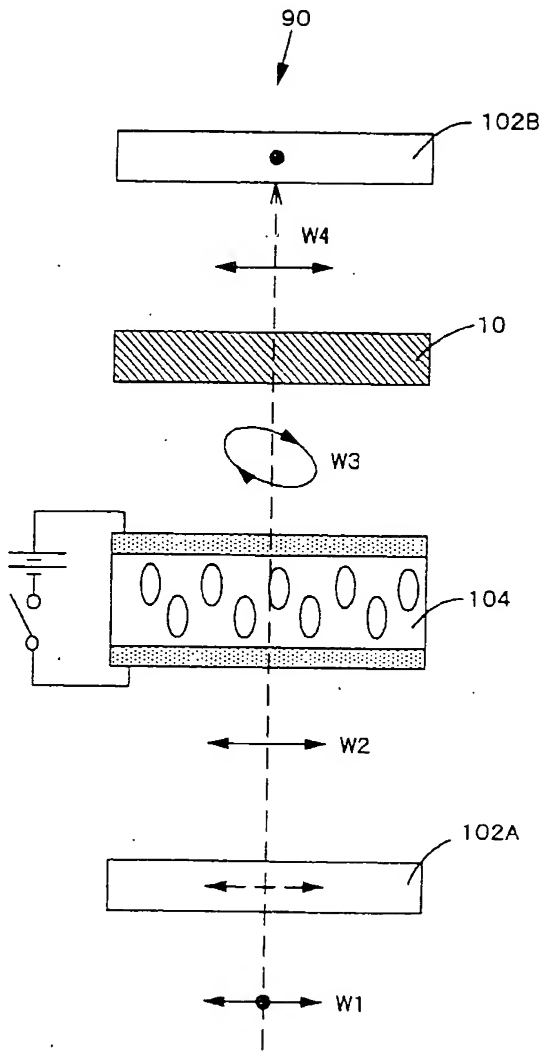

90
102B
W4
10
W3
104
W2
102A
W1

Fig. 2

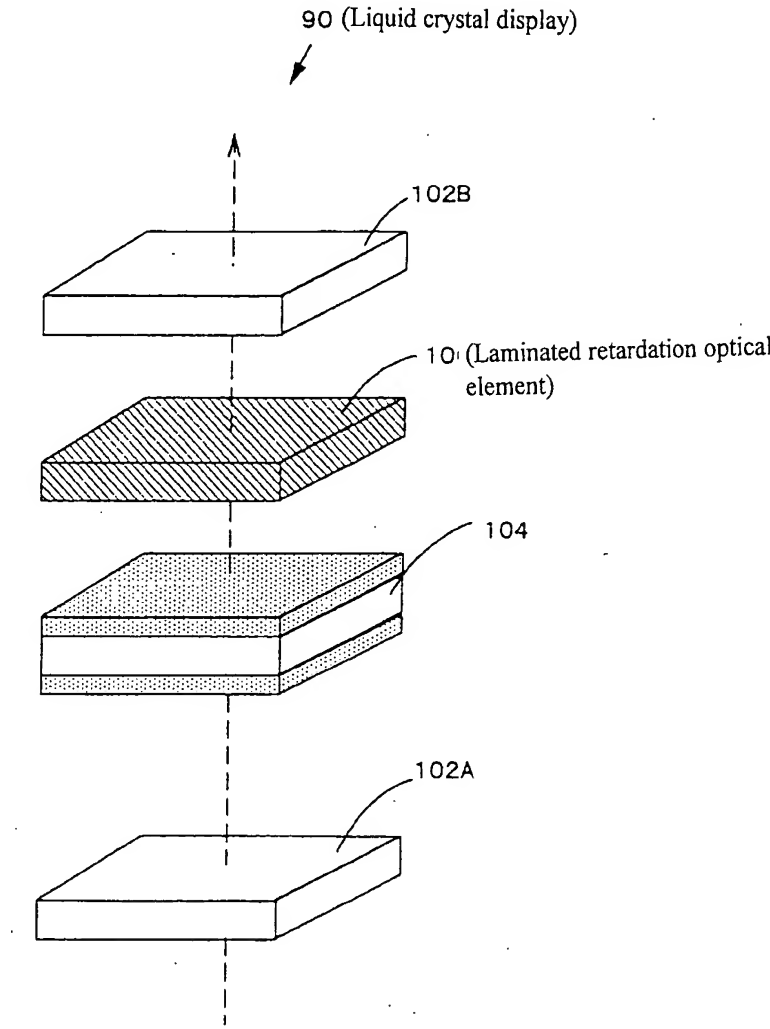

90 (Liquid crystal display)
102B
10 (Laminated retardation optical element)
104
102A

Fig. 1

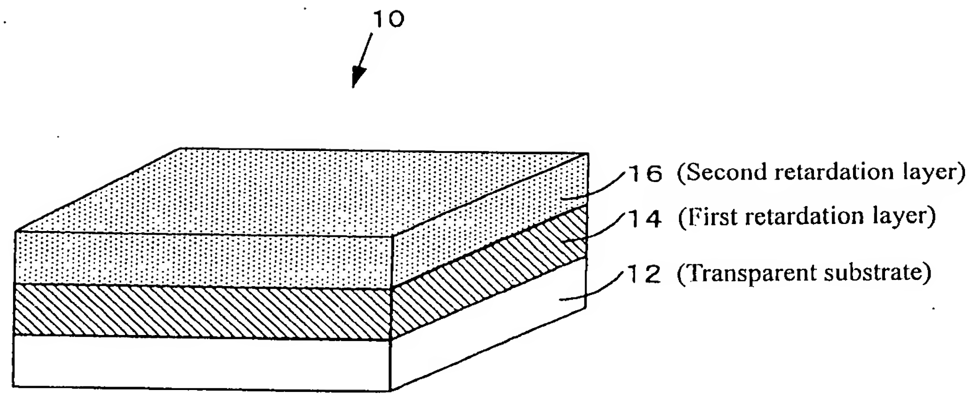
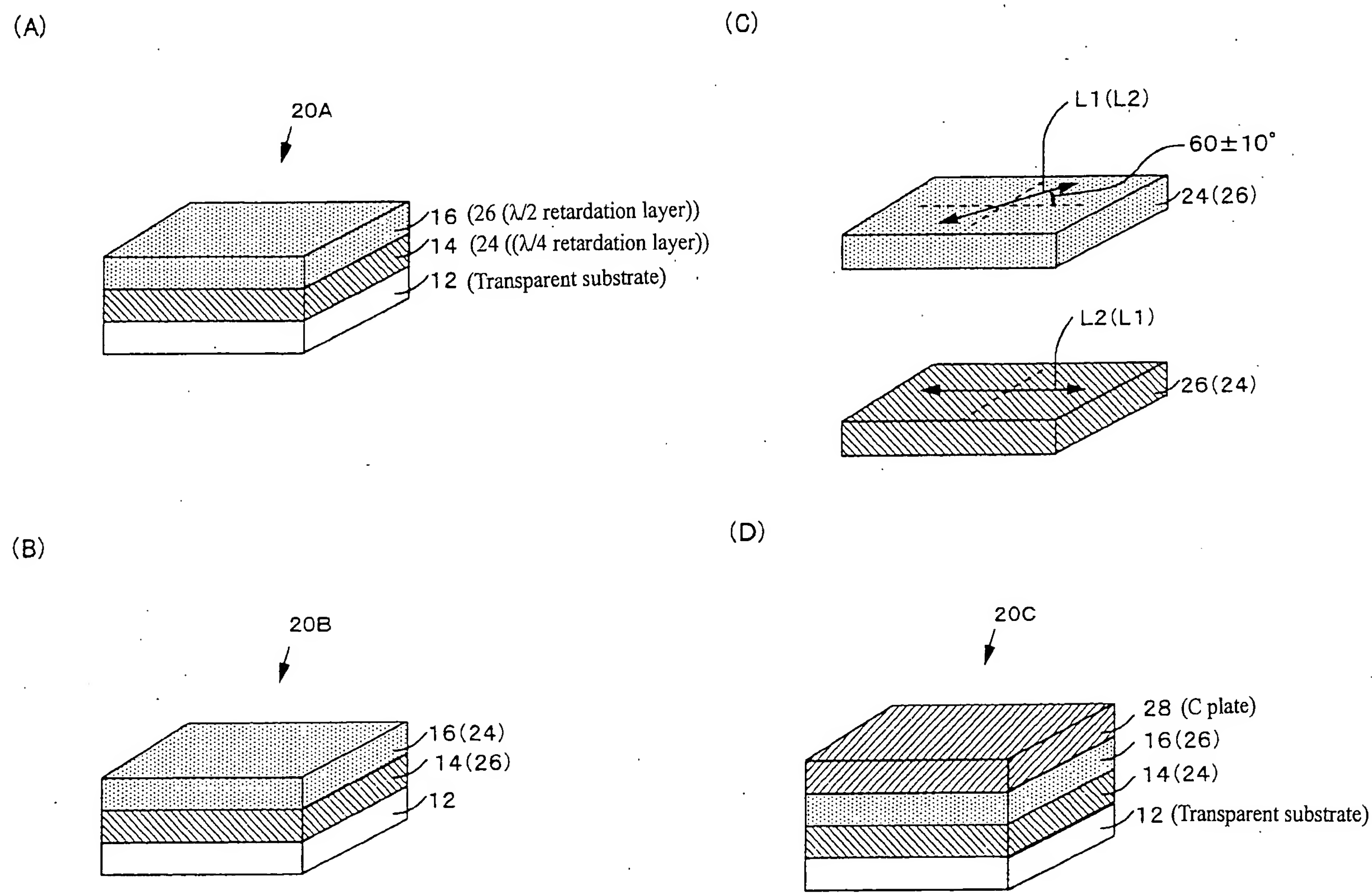

10
16 (Second retardation layer)
14 (First retardation layer)
12 (Transparent substrate)

Fig. 3



(A)
20A
16 (26 (λ/2 retardation layer))
14 (24 ((λ/4 retardation layer))
12 (Transparent substrate)
(B)
20B
16(24)
14(26)
12
(C)
L1(L2)
60±10°
24(26)
L2(L1)
26(24)
(D)
20C
28 (C plate)
16(26)
14(24)
12 (Transparent substrate)

Fig. 4

(A)

(B)

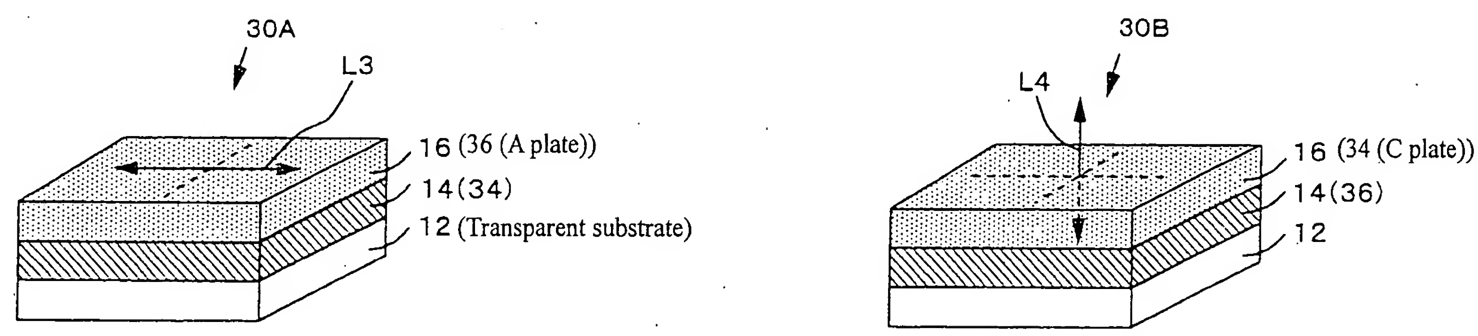

30A
L3
16 (36 (A plate))
14(34)
12 (Transparent substrate)
30B
L4
16 (34 (C plate))
14(36)
12

Fig. 5

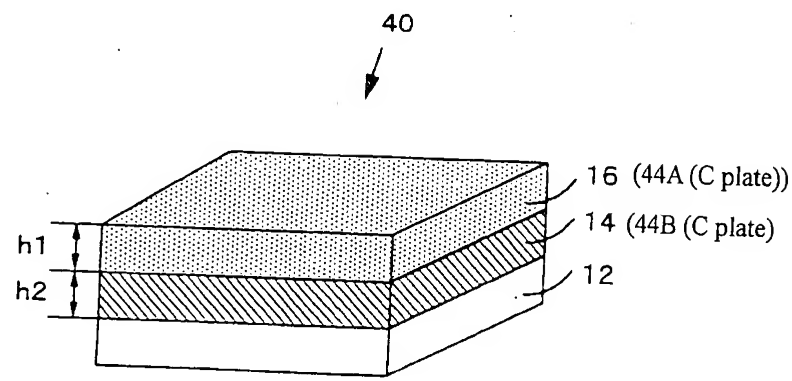


Fig. 6

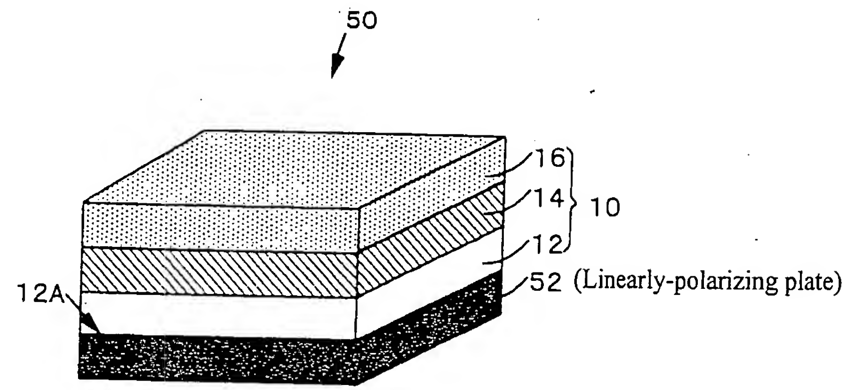


Fig. 7

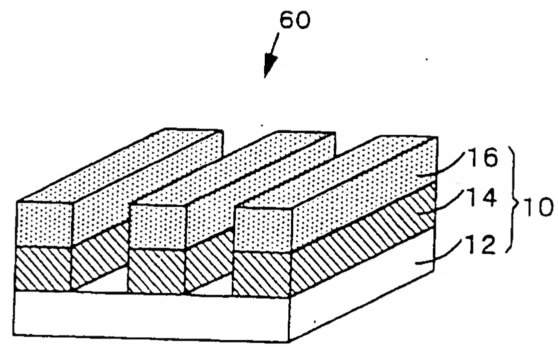


Fig. 8

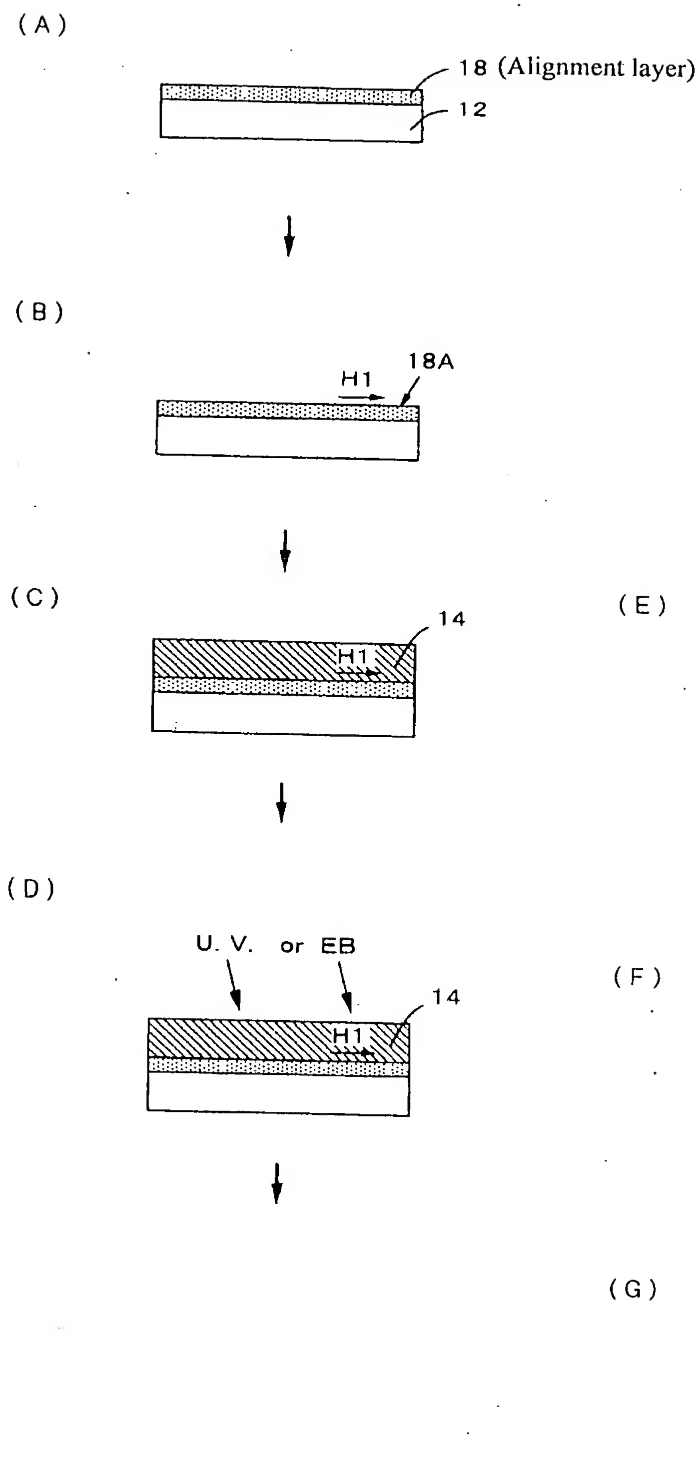

(A)
18 (Alignment layer)
12
(B)
H1
18A
(C)
14
H1
(D)
U. V. or EB
14
H1
(E)
14A
(F)
U. V. or EB
16
H2
H1
(G)
16
H2
H1

Fig. 9

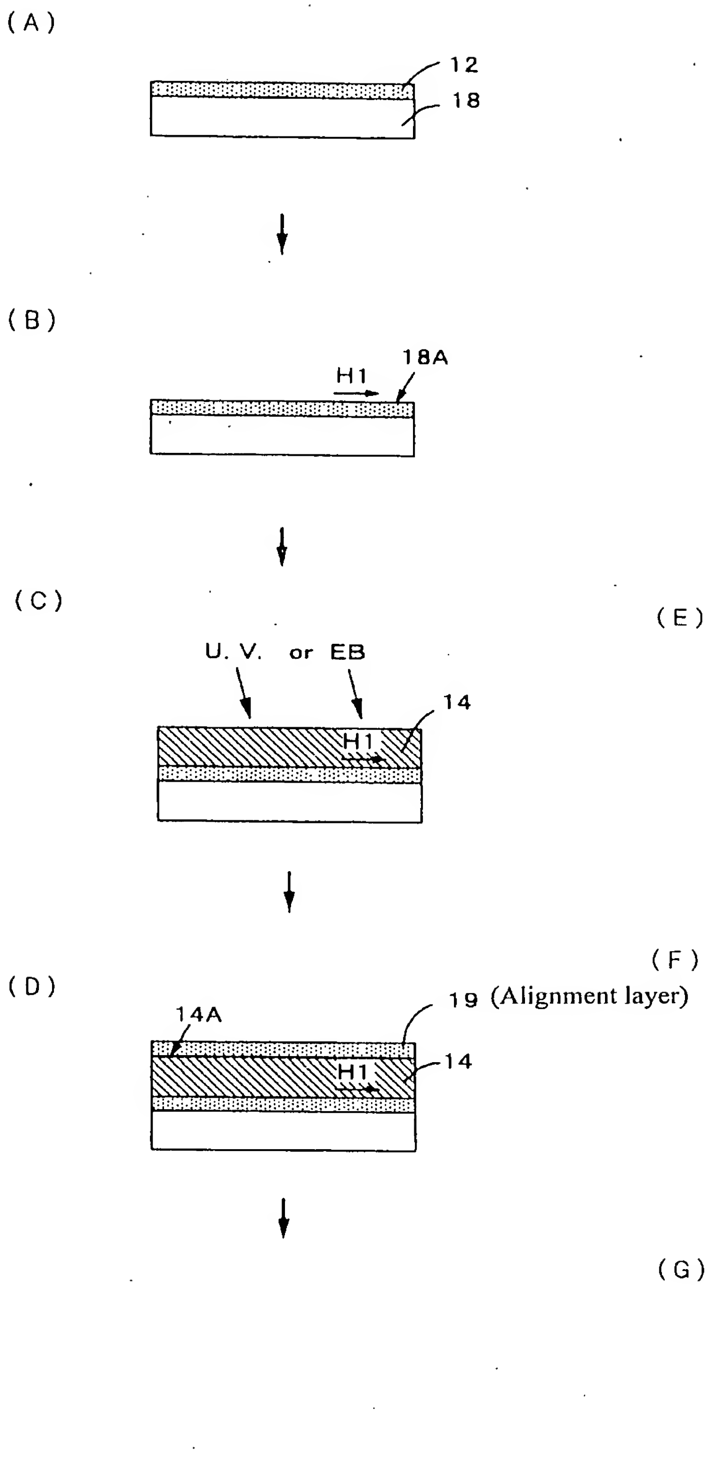
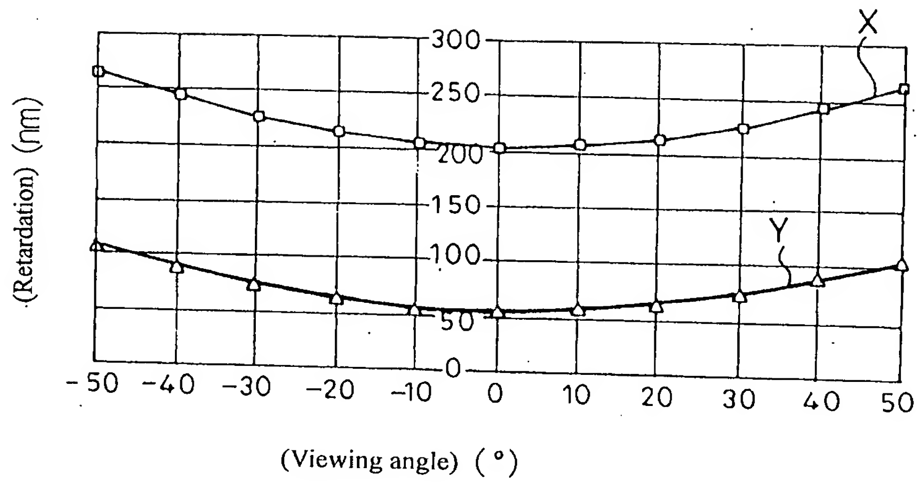
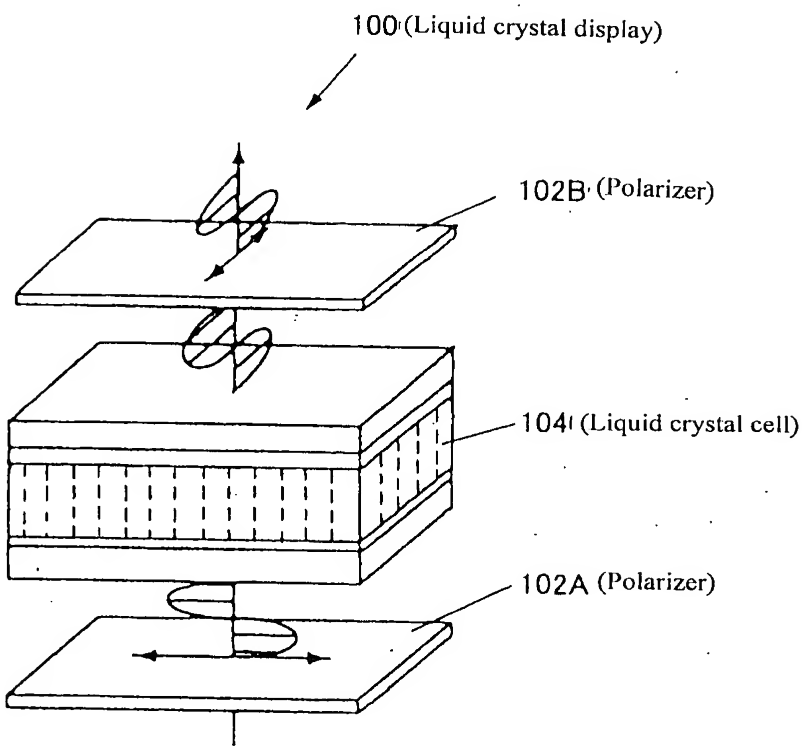

(A)
12
18
(B)
H1
18A
(C)
U. V. or EB
14
H1
(D)
14A
19 (Alignment layer)
14
H1
(E)
H2
H1
(F)
U. V. or EB
16
H2
H1
(G)
16
H2
H1

Fig. 10



X
Y
300
250
200
150
100
50
0
(Retardation) (nm)
-50
-40
-30
-20
-10
0
10
20
30
40
50
(Viewing angle) (°)

Fig. 11



100 (Liquid crystal display)
102B (Polarizer)
104 (Liquid crystal cell)
102A (Polarizer)

Fig. 12

[Document Type] ABSTRACT OF THE DISCLOSURE

[Abstract]

[Object]

To provide: a laminated retardation optical element that can effectively compensate for the change in the optical properties of a liquid crystal cell while achieving high productivity at the same time; a process of producing such an element; and a liquid crystal display comprising the said laminated retardation optical element.

[Means for Solving the Problems]

A laminated retardation optical element 10 comprising: a first retardation layer 14; and a second retardation layer 16 that is optically bonded to the said first retardation layer 14 in this order on a transparent substrate, wherein at least one of the said first retardation layer 14 and second retardation layer 16 comprises a cross-linked nematic liquid crystal or a cross-linked nematic liquid crystal and a cross-linked chiral agent as principal component.

[Selected Figure]

Fig. 3